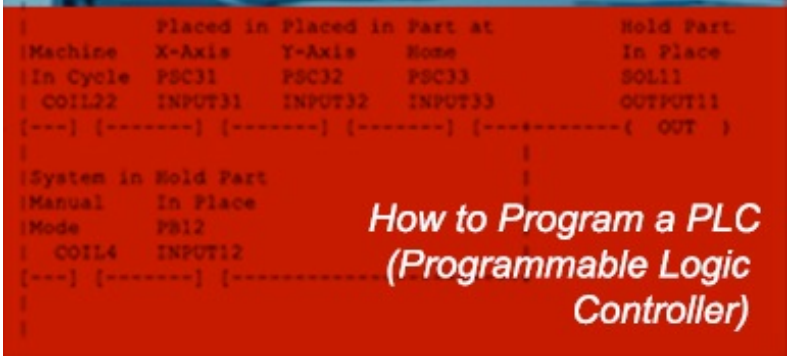
Beginner's Guide to PLC Programming

by Neal Babcock



Beginner's Guide To PLC Programming

How to Program a PLC (Programmable Logic Controller)

By Neal Babcock

Industrial Automation Series

engineer-and-technician.com

Beginner's Guide to PLC Programming
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Introduction to PLCs

Nearly all the industrial equipment that you find in a modern manufacturing facility shares one thing in common - computer control. The most commonly used controller is the PLC, or the Programmable Logic Controller, using a programming language called Ladder Logic. The language was developed to make programming easy for people who already understood how switches, relay contacts and coils work. Its format is similar to the electrical style of drawing known as the “ladder diagram”.

Originally, there were only a few functions available in this language, but as times have progressed, many more higher-level functions have been introduced. We are going to stick to the basic, commonly used functions here. Also, this text will not replace the user's manual that comes with a PLC, but it will give you a big head start if you have never programmed a PLC.

This course is intended to provide an introduction to the programming methods used in PLCs and give the reader a solid, basic understanding of the language of Ladder Logic.

After you complete this course, you may be interested in learning about hardware-specific software and programming techniques. Modern Media offers a book entitled PLC Programming Techniques *How to Program an Allen-Bradley SLC 500 with Rockwell Automation’s RSLogix.* This ebook shows, step-by-step, how to create a program from scratch in Allen-Bradley’s RSLogix 500. To learn more, please visit engineer-and-technician.com.

Ladder Logic

I have summarized the terms and techniques you need to know if you are going to work with ladder logic. It is not a comprehensive summary, as that would take volumes of text, but if you are just starting out, the information in this book will be very helpful. Every PLC programmer, no matter what skill level, must have learned the principles described in this book at one point in time. There is simply no way around it.

I have included a program for a simple machine that lets you really understand how Ladder Logic works.

To effectively write a program, or even edit one, the programmer must know how to visualize the effects of the changes he will make. In other words, you have to be able to look at the logic “on paper” and imagine how it will work when it is entered into the PLC. This course will teach you how to do that.

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There are many types of PLCs, and differences among PLCs, but what is discussed here should be common to all types. After you read and understand this, you will have a clear understanding of the structure of this type of programming. In the real world of industrial automation, the methods presented in this document may be all that many people will ever need to know.

The Dialect of PLCs

Let's define some terms and symbols:

BIT - an address within the PLC. It can be an input, output or internal coil, among others.

RUNG - A section of the PLC ladder program that terminates in an output function of some type.

HARDWIRED INPUT - a physical connection to the PLC from an input device (switch or sensor, etc.)

A hardwired input is labeled INPUT in our example.

HARDWIRED OUTPUT - a physical connection from the PLC to an output device (relay or pilot light, etc.)

A hardwired output is labeled OUTPUT in our example.

INTERNAL COIL
This is a programmable bit used to simulate a relay within the PLC. The internal coil has no connection to the outside world. It does not connect to an output card. Internal coils are used to store information. The "contacts" of this "relay" can then be used multiple times in other parts of the program.

An internal coil is labeled COIL in our example.

--] [-- Normally Open Contact
When used with a hardwired input, this instruction is off until there is a voltage applied to the input. The bit address then goes high, or on, and the instruction becomes "true." It works the same way when it has the same address as an internal coil, except that the coil must be turned on by logic in the program.

--] / [-- Normally Closed Contact
This is an inverted normally open contact. When used with a hardwired input, this instruction is "true" until there is a voltage applied to the input. It then goes low, or off, and becomes "false." It also can be used with an internal coil, becoming true when the coil is off and becoming false when the coil is on.

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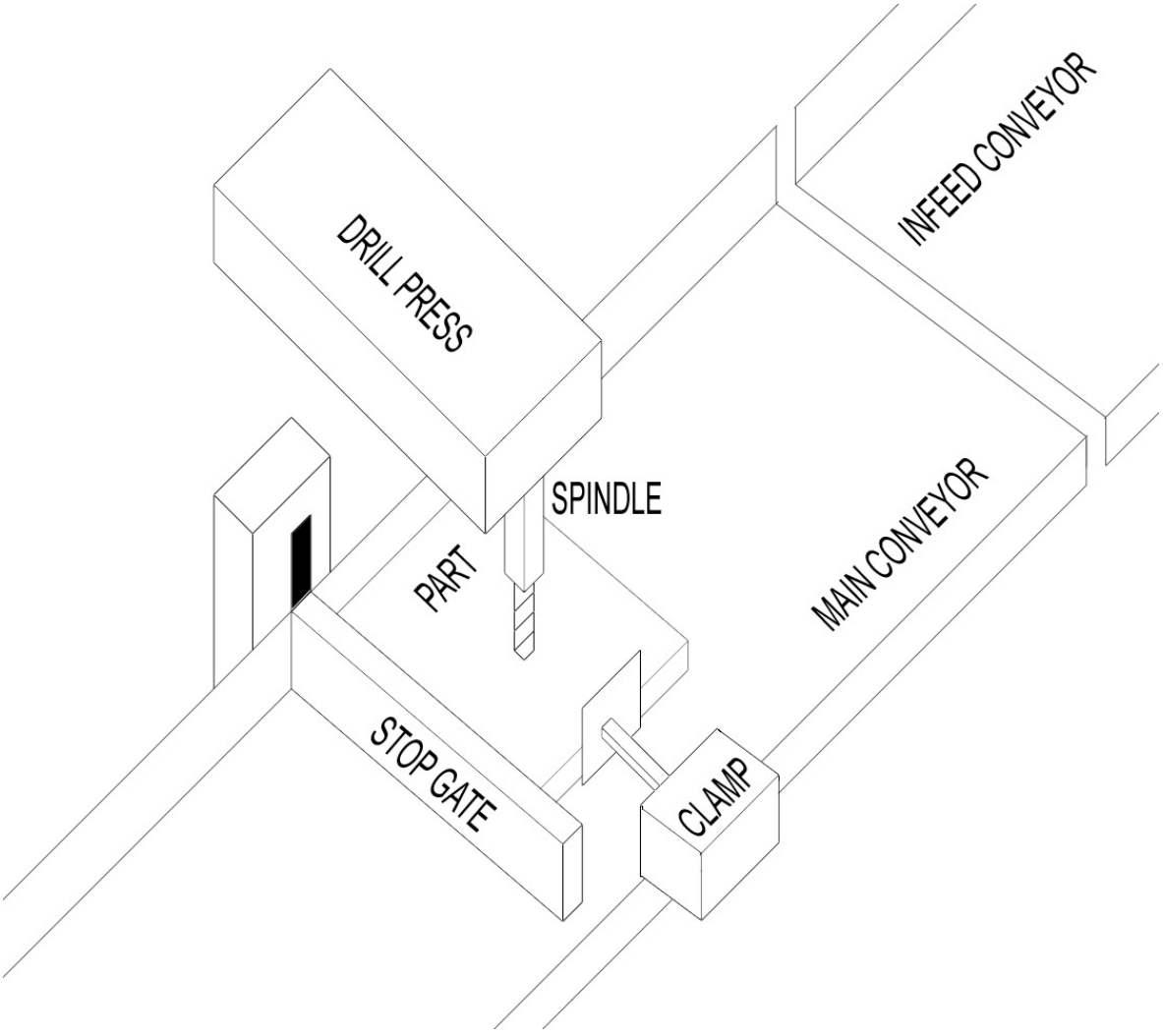
The Automated Drill Press

Now let's jump right into a project. The best way to learn a programming language is to look at a real world example. However, before you can do any programming, you must have a clear understanding of how the machine works. Let's say a furniture manufacturer needs to drill a 3/8" hole in a certain spot on a piece of wood. The entire process needs to be automatic. The mechanical and electrical engineers bring you an isometric drawing like the one shown here. Mechanical details have been omitted for clarity, as is often the case in a "concept" drawing.



The main conveyor will transport the part into the machine where the part will meet a pneumatically actuated stop gate. At that time, another pneumatic cylinder will actuate a clamp that will push the part back against the conveyor wall. This will hold the part in place during the drilling process. Photocells will verify that the part is in position; the spindle will lower and

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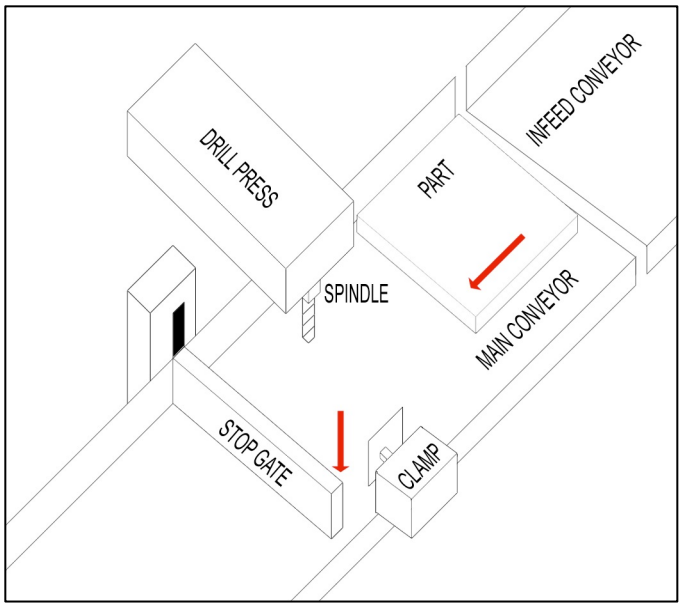
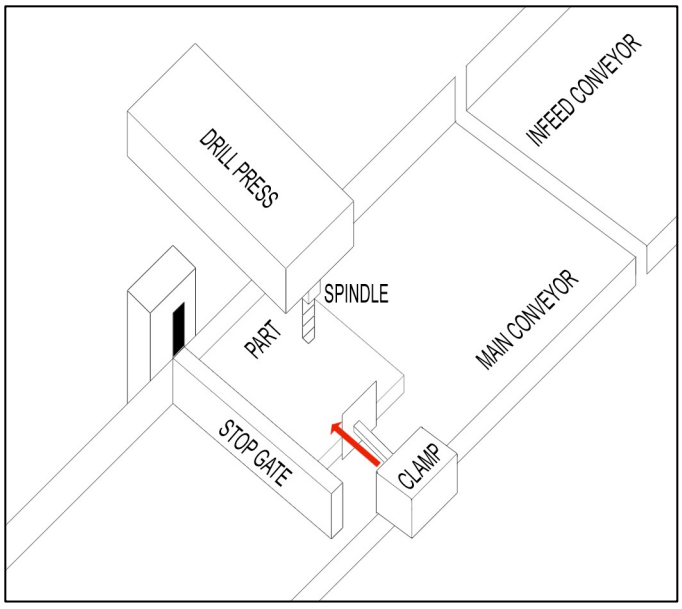
proceed to drill a hole in the part. After the hole has been drilled and the spindle has retracted to its home position, the clamp will release, the stop gate will raise and the part will exit. The cycle then repeats itself for each part that comes down the line.

Sequence of Operation

Here is a more detailed explanation of the drilling process:



When the machine starts, the stop gate lowers and the part is moved into position by the main conveyor.



Optical sensors (photoeyes) determine when the part is in place.

When the part is positioned correctly, a clamp extends to hold the part in place.

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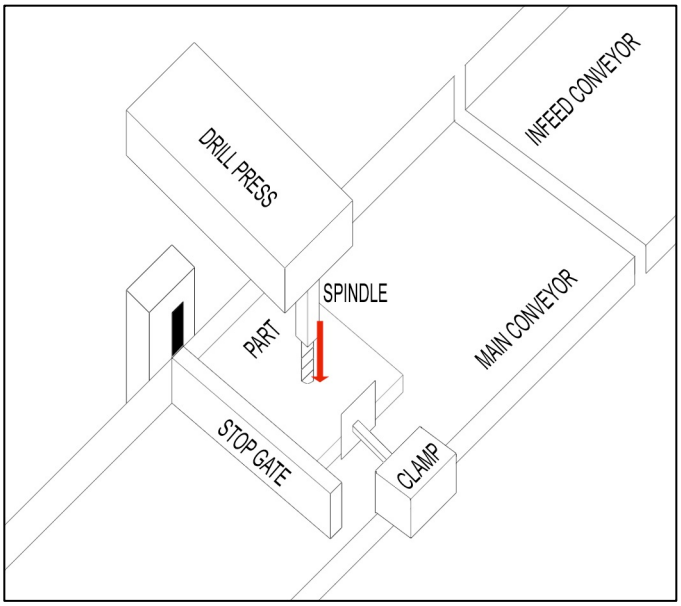
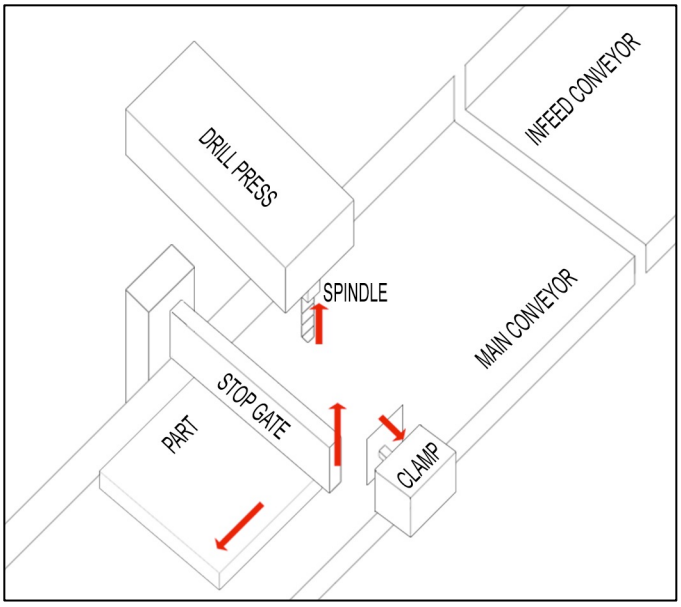


The spindle of the drill press is lowered, and the hole is drilled in the part.

A sensor in the drill press spindle tells the PLC when the spindle has reached the end of its travel.



After the hole is drilled, the spindle retracts, the clamp retracts, the stop gate is lifted and the part is carried out of the machine by the main conveyor.

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The Program

Now that you understand what has to be done and how it is to be accomplished by the mechanical equipment, you can begin writing the program.

The text in the `fixed font` is basically the information that you would see if you were looking at the monitor of the computer or a printout. In actual practice, the fonts used in PLC software vary widely. For the purposes of this book, we want to easily differentiate the program logic from our explanations of the logic.

A series of asterisks `(*****)` indicates a "rung comment." This is descriptive text added to the program, and is seen on the programming monitor, but has no affect on the logic. For purposes of this manual, I have placed additional explanations between rungs.

Use a title to name the program and include any general information.

```
|
|       ____________________________________________________
|       |                                                   |
|       |  AUTOMATIC DRILL PRESS MACHINE CONTROL            |
|       |  PRODUCTION LINE #3                               |
|       |  REVISION 2                                       |
|       |___________________________________________________|
```

Machine Safeties

It is best to start a program by evaluating any safety switches and setting a master bit. This type of bit is what we call an internal coil. It has no hardwired connection to the outside world. In this case, a latch is used to set an internal “System Running” bit. The “latch” is accomplished by putting a normally open contact around the Start System pushbutton input.

If the emergency stop is clear, and the machine guard is in place, and there is no system fault the operator may press the start button to set the latch. If the stop button is pushed or a previous conditions ceases to exist, the “System Running” latch will drop out.

Most of the time, the order of the bits in a rung doesn't matter. We could have rearranged any of the bits in this rung, though we would still have to put the latch around the Start pushbutton. The PLC wouldn't care and the output coil would still respond the same. However, to make the rung easier to read, I try to place bits from left to right in order of importance. If the E-Stop is not cleared, then nothing else should matter anyway. Having the safety guard in place is more important than a system fault. Now, if those requirements have been met, we can press the start button. And we don't care about the stop button until we have pushed the start button.

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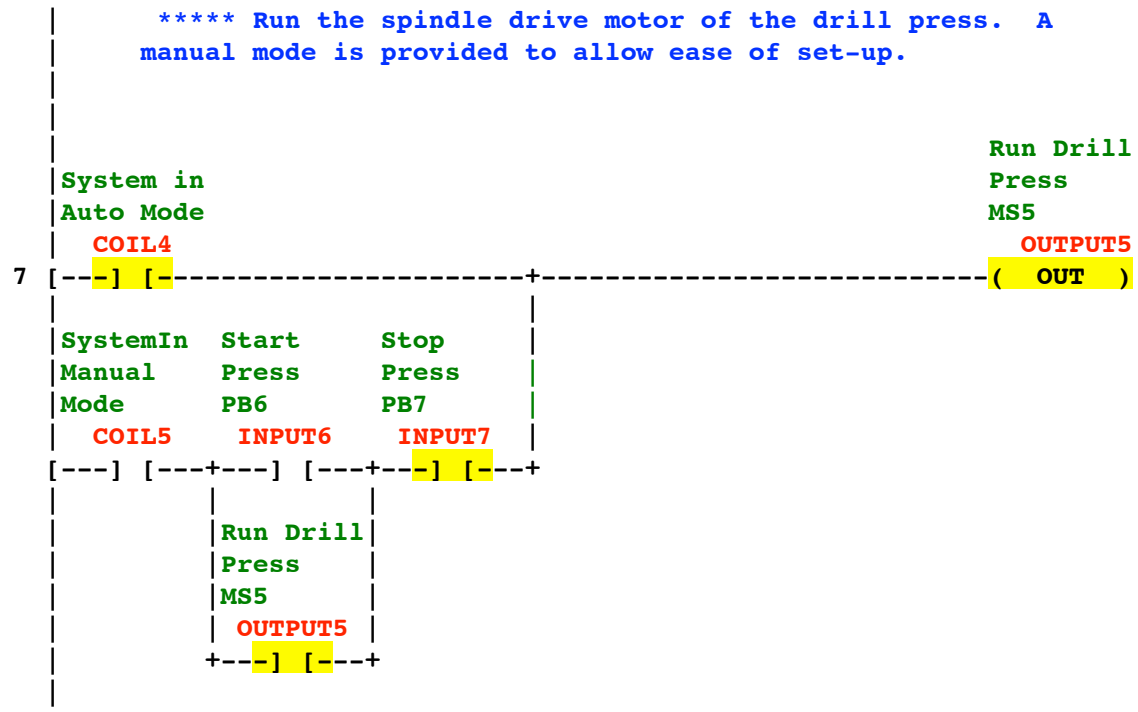
Run The Spindle Drive Motor

This rung turns on the drill press spindle motor. It will come on immediately in automatic mode, but it can also be controlled by the “Start Press” and “Stop Press” switches in manual mode.



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Low Compressed Air Pressure

It is a good idea to keep track of the compressed air pressure. The machine will not operate properly if there is insufficient air pressure. You can put it on a fairly long time delay, because you don't care about momentary drops in pressure, like a second or two. But when it does drop beyond the lower limit for enough time, you want the machine to stop.

You also want it to latch so you know why the machine stopped running. The air pressure could come back up before the operator sees the pilot light, and he would be left scratching his head. The latch is reset by the Reset System pushbutton.

```
    |      ***** Detect abnormally low compressed air pressure.
    |
    |
    |AirPressr                                              +--Air      -+
    |Normal                                                 |  Pressure  |
    |PS27                                                   |  Abnormal  |
    | INPUT27                                              TIMER27       |
 22 |---]/[-------------+-----------------------------------+---4SEC-----+
    |                   |
    |Air       Reset    |
    |Pressure  System   |
    |Abnormal  PB1      |
    | TIMER27   INPUT1  |
    |---] [-------]/[---+
    |
    |
    |      ***** Indicate abnormally low air pressure.
    |
    |Air                                                        Low Air
    |Pressure                                                   Pressure
    |Abnormal                                                   PL26
    | TIMER27                                                   OUTPUT26
 23 |---] [---+-------------------------------------------------(  OUT   )
    |         |
    |Pilot    |
    |Light    |
    |Test     |
    |  COIL2  |
    |---] [---+
```


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Motor Starter Overload

If the auxiliary contacts in the motor starters don't pull in after one second, there is some kind of problem. You have to look at each one individually.

```
    |      ***** The starter is assumed to be overloaded if the aux
    |      contact does not pull in after 1 second.
    |
    |RunInfeed InfedConv                                    +--Infeed   -+
    |Conveyor  Running                                      |  Conveyor  |
    |MS1       MS1AUX                                       |  Overload  |
    | OUTPUT1   INPUT20                                     TIMER1       |
 24 [---] [-------]/[--------------------------------------+--1SEC------+
    |
    |
    |
    |Run Main  Main Conv                                    +--Main     -+
    |Conveyor  Running                                      |  Conveyor  |
    |MS2       MS2AUX                                       |  Overload  |
    | OUTPUT2   INPUT23                                     TIMER3       |
 25 [---] [-------]/[--------------------------------------+---1SEC-----+
    |
    |
    |Run Drill DrillPres                                    +--Drill    -+
    |Press     Running                                      |  Press     |
    |MS5       MS5AUX                                       |  Overload  |
    |OUTPUT5    INPUT24                                     TIMER5       |
 26 [---] [-------]/[--------------------------------------+---1SEC-----+
    |
    |
```


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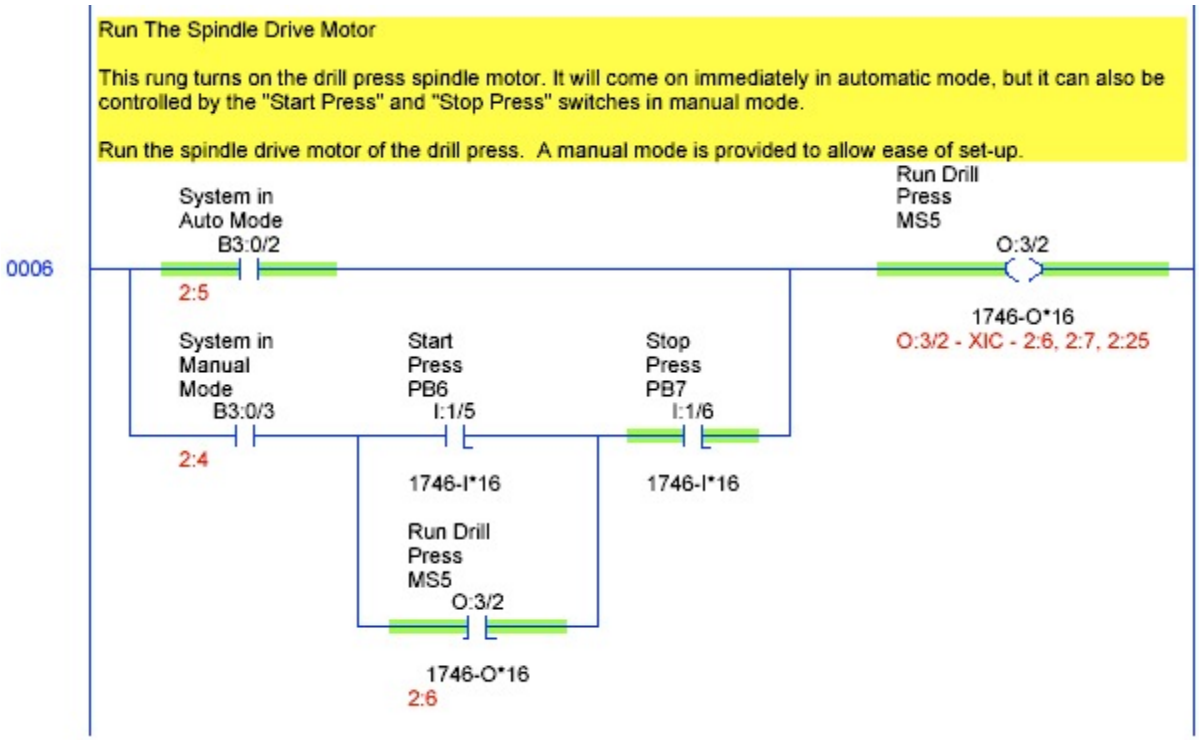
The Automated Drill Press in RSLogix 500

The most popular and most widely used manufacturer of PLCs is Rockwell Automation, who produces the Allen-Bradley MicroLogix and SLC series of PLCs. The MicroLogix and SLC families of processors and I/O modules are all programmed using Rockwell's proprietary software known as RSLogix.

I used a generic style of ladder logic in the first part of the book to explain the fundamentals of ladder logic. This style was chosen because it applies to all types of PLCs.

To give you a better understanding of how the program would look in a real world situation, I have included the same Automated Drill Press program as it would appear if it were written in Allen-Bradley's RSLogix.

Here is an example:


Run The Spindle Drive Motor
This rung turns on the drill press spindle motor. It will come on immediately in automatic mode, but it can also be controlled by the "Start Press" and "Stop Press" switches in manual mode.
Run the spindle drive motor of the drill press. A manual mode is provided to allow ease of set-up.
0006
System in Auto Mode
B3:0/2
2:5
Run Drill Press MS5
O:3/2
1746-O*16
O:3/2 - XIC - 2:6, 2:7, 2:25
System in Manual Mode
B3:0/3
2:4
Start Press PB6
I:1/5
1746-I*16
Stop Press PB7
I:1/6
1746-I*16
Run Drill Press MS5
O:3/2
1746-O*16
2:6

I will give you a brief outline of the differences between the generic format of ladder logic that I used and RSLogix's format:

First, though, the address descriptions and the rung comments are the same in the RSLogix program as they are in the generic program. Despite what the numbers say under the instruction, "System in Auto Mode" is the same bit here as the "System in Auto Mode" is in the generic program.

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Outputs
Allen-Bradley labels their outputs starting with a capital “O”, whereas we used “output” in the generic program. In the rung above, “O:3/2” is the same bit as “OUTPUT5” in our generic program.

“1746-O*16” indicates the type of output module.

Inputs
Allen-Bradley labels their inputs starting with a capital “I”, whereas we used “input”. In the rung above, “I:1/5” is the same bit as “INPUT5” in our generic program.

“1746-I*16” indicates the type of input module.

Coils (internal bits)
Allen-Bradley labels *most* their internal “coils” starting with a capital “B3”, whereas we used “out”. In the rung above, “B3:0/2” is the same bit as “COIL4” in our generic program.

Cross Reference
The RSLogix program shows cross-referencing. The number “2:5” under the first instruction means that the output (or, “coil”) for that address is found in file 2, rung 5.

“2” is the first, and default, data file of a ladder in RSLogix.

The output O:3/2 shows that its “contacts” are found on rungs 6, 7 and 25 of data file 2.

Rung Numbers
RSLogix starts with rung 0000 – the generic program starts with rung 1, so the rung numbers shown in the RSLogix program will be one less than the rung numbers in the generic program.

Logic Flow
Bits that are true in RSLogix are shown with a green highlight. This RSLogix ladder printout above is a snapshot showing the **system in automatic mode, the part is in place and the drill bit is being lowered**. There are no faults.

Other Information
RSLogix will provide a variety of information regarding the program and hardware. I have included those pages here.

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Ensure all machine safeties have been made to allow the system to be enabled.

0000

EmergStop Cleared CR1 I:1/4 — 1746-I*16

Guard in Place LS26 I:2/4 — 1746-I*16

System Fault B3:0/12 — 2:33

Start System PB2 I:1/1 — 1746-I*16

System Running B3:0/0 — 2:0

Stop System PB3 I:1/2 — 1746-I*16

System Running B3:0/0

B3:0/0 - XIC - 2:0, 2:3, 2:4
2:5

Perform a pilot light test upon clearing the emergency stop.

0001

EmergStop Cleared CR1 I:1/4 — 1746-I*16

Pilot Light Test Time

TON
Timer On Delay
Timer T4:0
Time Base 1.0
Preset 2<
Accum 2<

EN

DN

T4:0/DN - XIO -2:2

Test the pilot lights.

0002

EmergStop Cleared CR1 I:1/4 — 1746-I*16

Pilot Light Test Time T4:0/DN — 2:1

Pilot Light Test B3:0/1

B3:0/1 - XIC - 2:3, 2:7, 2:14
2:20, 2:22, 2:27
2:30

Indicate the system is operational.

0003

System Running B3:0/0 — 2:0

Pilot Light Test B3:0/1 — 2:2

System Running PL20 O:3/7 — 1746-O*16

Determine the mode of machine operation.

0004

System Running B3:0/0 2:0

System in Auto Mode SS4 I:1/3 1746-I*16

System in Manual Mode B3:0/3

B3:0/3 - XIC - 2:6, 2:15, 2:16 2:18

0005

System Running B3:0/0 2:0

System in Auto Mode SS4 I:1/3 1746-I*16

System in Auto Mode B3:0/2

B3:0/2 - XIC - 2:6, 2:8, 2:11 2:13

Run the spindle drive motor of the drill press. A manual mode is provided to allow ease of set-up.

0006

System in Auto Mode B3:0/2 2:5

System in Manual Mode B3:0/3 2:4

Start Press PB6 I:1/5 1746-I*16

Stop Press PB7 I:1/6 1746-I*16

Run Drill Press MS5 O:3/2 1746-O*16 2:6

Run Drill Press MS5 O:3/2

1746-O*16

O:3/2 - XIC - 2:6, 2:7, 2:25

Indicate the drill press is running.

0007

Run Drill Press MS5 O:3/2 1746-O*16 2:6

Pilot Light Test B3:0/1 2:2

Drill Press Running PL21 O:3/8 1746-O*16

Run the infeed conveyor if the machine is in automatic mode.

0008

System in Auto Mode B3:0/2 — 2:5

Run Infeed Conveyor MS1 O:3/0 — 1746-O*16

O:3/0 - XIC -2:23

Ensure there are no parts in the machine to start the drilling cycle.

0009

Placed in X-Axis PSC31 I:2/6 — 1746-I*16

Placed in Y-Axis PSC32 I:2/7 — 1746-I*16

Part at Home PSC33 I:2/8 — 1746-I*16

Part Cleared PSC34 I:2/9 — 1746-I*16

No Part In Machine B3:0/4

B3:0/4 - XIC -2:11

Ensure all components are at home.

0010

Hold Part in Place SOL11 O:3/5 — 1746-O*16 — 2:15

Drilling Stop Gate SOL12 O:3/6 — 1746-O*16 — 2:12

Spindle Raised PRS35 I:2/10 — 1746-I*16

Machine at Home B3:0/5

B3:0/5 - XIC -2:11

Begin the cycle when the part has cleared the machine and all components are at home. Bit B3:0/6 will stay on during the entire drilling cycle and drop out when an end of cycle signal is generated.

0011

System in Auto Mode B3:0/2 — 2:5

No Part In Machine B3:0/4 — 2:9

Machine at Home B3:0/5 — 2:10

End of Machine Cycle B3:0/8 — 2:19

Machine in Cycle B3:0/6 — 2:11

Machine in Cycle B3:0/6

B3:0/6 - XIC - 2:11, 2:12, 2:15 2:16, 2:17, 2:18 2:19, 2:28, 2:31

Lower the stop gate to stop the part under the spindle.

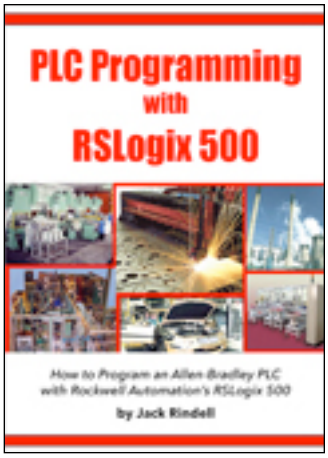
0012

Machine in Cycle B3:0/6 — 2:11

Drilling Stop Gate SOL12 O:3/6 — 1746-O*16

O:3/6 - XIO -2:10

Supplementary recommendations that will help, available at engineer-and-technician.com.



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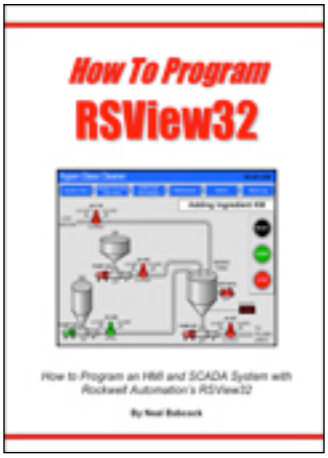

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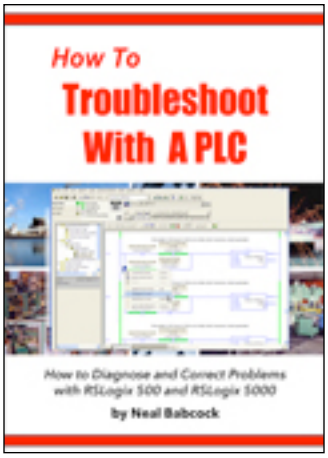

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